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EXPERT MATTERS DISCUSS
PROTECTOR OF MODERN TANKS

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Tank armor consists of steel plates and steel castings which are riveted or welded together to form the armored body and turret of the tank. Special steel containing 0.25-0.45 percent carbon is used for the armor of modern tanks. The more carbon in the steel, the harder it is, but increasing the carbon content also makes the steel more brittle. Brittle steel is not suitable for armor, which should be hard and at the same time ductile. The combination of these qualities is obtained by complex heat treatment of the metal and addition of nickel, chrome, and molybdenum. Some of the elements added increase the strength of steel (chrome, silicon, manganese), some increase the ductility (nickel, manganese), and some make it easier to machine and heat-treat the steel (nickel, chrome).

To combine a high degree of surface hardness with ductility, the armor is sometimes casehardened. In the casehardening process, a thin layer of the armor's surface is saturated with carbon while the rest of the armor contains comparatively little carbon. Armor of this kind withstands armor-piercing bullets and does not split when struck by shell fragments. Case-hardening is especially important when tank armor up to 15-20 millimeters thick is used for protection against bullets and shell fragments. Since the armor of modern tanks is primarily designed for protection against shells rather than bullets, and since it is 200 millimeters or more thick, homogeneous, noncasehardened steel is used for this purpose.

Interaction of Projectile and Armor

The ordinary armor-piercing shell shatters armor by its kinetic energy, which is expressed by the formula:

$$W \text{ equals } \frac{MV^2}{2}$$

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where M equals the mass of the projectile, which equals its weight G divided by the acceleration due to gravity g :

$$M \text{ equals } \frac{G}{g} \text{ equals } \frac{G}{9.81} \frac{\text{kilograms} \times \text{second}^2}{\text{m}}$$

V is the speed of the projectile at the moment it strikes the armor.

If the projectile strikes the armor perpendicularly, all of its kinetic energy goes toward knocking out a "plug", that is, shattering the armor. The inertia of the armor makes it resist bending. The higher the speed of the projectile, the less time there is for the armor to bend, and the greater proportion of the kinetic energy of the projectile goes toward knocking out a plug.

The projectile rarely strikes the armor perpendicularly, but rather at an angle to the perpendicular. If the angle is small, the force acting on the projectile from the armor (reaction of the armor), together with the inertia of the projectile (applied at the center of gravity), tend to turn the projectile, reducing the angle and increasing the projectile's capacity for piercing the armor. This is called shifting of the projectile. If the angle is large, the forces tend to turn the projectile in the other direction (increasing the angle), causing it to ricochet. Thus, the strength of the armor will depend on the angle at which the projectile meets it: the greater the angle, the less chance that the armor will be shattered. To increase this angle, the armor is mounted obliquely wherever possible. Oblique armor lengthens the distance the projectile must penetrate and is thus equal in protective value to a thicker plate of vertical armor. This makes it possible to make oblique sheets thinner and thus reduce the weight of the armor.

Small angles of deviation from the perpendicular (up to 10 degrees) have little effect on the piercing ability of the projectile. For this reason, the angle of inclination of the armor is usually no less than 20 degrees. At an angle of 50 degrees the projectile ricochets.

The kinetic energy of the projectile depends on the velocity with which it strikes the armor. The greater the distance from the gun to the point of impact, the greater the loss in velocity of the projectile in flight, and the smaller the impact velocity. It must be noted that the impact velocity is squared in the formula so that reducing it by two times decreases the kinetic energy and hence the piercing ability of the projectile by four times.

The protective thickness of armor is that thickness with which the inner (rear) surface of the armor does not break, that is, does not show cleavage or fissures. With a muzzle velocity of 750-800 meters per second, the protective thickness of the armor equals 0.8 to 1.3 times the caliber of the projectile (the smaller figure corresponding to a 37-millimeter projectile and the larger to a 75 millimeter projectile).

Subcaliber and Cumulative Projectiles

The subcaliber projectile consists of a soft iron body, lightened as much as possible by grooves, a very hard, relatively heavy core made of tungsten (a very hard metal with a specific gravity three times that of steel), and a ballistic cap made of plastic or aluminum. Reducing the total weight of the projectile makes it possible to give it a greater muzzle velocity (1,000-1,200 meters per second). The ballistic cap collapses when it strikes the armor, and the core, whose diameter is smaller than the caliber of the projectile (hence the name), pierces the armor.

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In this way the body of the projectile gives part of its kinetic energy to the core, like a hammer hitting a nail. The small caliber of the core, its great hardness, and the guiding action of the projectile body, coupled with high muzzle velocity, make necessary a protective thickness of armor 1.2 to 2.0 times the caliber of the projectile at distances up to 500 meters.

The action of the cumulative projectile is based on the so-called cumulative effect. The explosive is inserted in the projectile in the form of a cone so that when it explodes, a directed current of gases with enormous pressure and very high temperature is formed. The burst wave, rebounding from the cone like rays of light reflected from a concave mirror, possesses enormous destructive force and easily shatters the armor, even if it is very thick. Impact velocity is of no importance with cumulative projectiles; hence, the protective thickness of the armor for this type of shell is the same for all distances and equals 0.8 to 1.0 times the caliber.

Other antitank weapons are magnetic cumulative mines, cumulative mines, self-propelled electric torpedoes, guided by wire from cover, and hand rocket launchers with cumulative shells.

The crew of the tank, the firing unit and armament, the basic machinery, and the fuel, oil, and water for it are situated so that they take up as little space as possible, at the same time, facilitating the combat operations of the crew and access to the units that have to be checked and serviced, and providing protection for the men and machinery. Thus, it is obvious that the smaller the dimensions of the tank, the better it is protected. Especially important is minimum height of the tank, permitting it to take cover in uneven terrain.

However, in determining the height of the body and turret, it must be kept in mind that the members of the crew in the turret have to work while standing or half sitting. Hence, taking into account the tank's clearance, the height of the tank body and turret cannot be made less than 2 meters.

In the modern tank with large caliber armament, the width of the upper part of the body is determined by the diameter of the turret ball race, which is almost 2 meters. If the diameter is smaller than 2 meters, it will be almost impossible for the gun crew to function efficiently. This minimum diameter, therefore, determines the width of the tank body.

Oblique armor gives greater protection to the tank, but large angles of inclination can only be used on the front and rear of the tank. It is usually impossible to make the sides of the tank sloping along their entire height. The body will either be too wide in the expanded part, making it impossible to transport the tanks by railroad, or it will be too narrow in the compressed part, making it impossible to house the machinery and placing the crew in cramped quarters. For these reasons, the side plates are most frequently made vertical, or made oblique only in the upper portion, especially if the body is expanded on top and overhangs the tracks.

The more hatches there are in the body, the more convenient it is to work in the tank and to service the machinery; but hatches, even when their covers are thicker than the body plates, greatly weaken the body.

In shelling a tank, a hit on the turret is most probable, and after that, a hit on the front or the upper portion of the sides. For this reason, the armor of the front of the body and of the turret in the majority of modern tanks is approximately one and a half times as thick as the armor on the sides. The horizontal plates of the top and bottom of the tank, since they are more should read, less vulnerable, are made 2-3 times thinner than the side plates.

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Besides the defense of tanks against artillery, discussed above, there are a number of secondary, but nevertheless vital, aspects of tank defense. Among these are defense against land mines by making the tank's bottom strong and secure, protection against the penetration of flaming liquids inside the tank, protection against the spread of fire inside the tank, and many others. Some of these problems have not yet been solved.

The Tank Turret

The turret is the most vulnerable part of the tank, and at the same time, holds the primary armament of the tank and the most important members of the crew. After the thickness of the armor, the shape of the turret has the greatest bearing on its protective value. The more rounded the tank turret is, the less chance there is of a projectile hitting it perpendicularly.

Cone-shaped turrets, which are widely used at present, combine the advantages of convex (cylindrical) and oblique armor. Optimum protection is given by spherical (ball-shaped) turrets.

Conversion from welded turrets to cast turrets created greater possibilities of giving the turret the desired shape. Cast turrets can be given any form, and a gradual change in armor thickness from front to rear and from top to base is more easily effected. If one adds to this, simplicity of production, it is easy to see why the use of cast turrets and castings of complete body parts has become widespread recently. It is true that cast steel is not as tough as rolled steel, but this is compensated for by the above-mentioned advantages.

Two theories of tank development conflicted in World War II: the German theory, based on high-speed, lightly armored tanks, and the USSR theory, based on well-armored, but, at the same time, rapid and heavily armed tanks. Pitted against USSR tanks, the German tanks were proved obsolete, and the German Army was compelled to re-equip its tank and mechanized troops completely. Rejection of the weakly armored (30 millimeters thick) T-III and T-IV tanks and conversion to heavily armored tanks like the Panther, Tiger, King Tiger, and finally, the superpower Mouse [myshonok; literally, "little mouse"] with armor 180-240 millimeters thick showed that German tank designers had been driven to an extreme, and had sacrificed mobility and mass utilization of tanks for the sake of armor protection.

Soviet tank builders, starting with the T-34 and KV tanks, continued their line of development, combining in their tanks the basic combat qualities: firepower, mobility, and armor protection, and not sacrificing one quality for another. USSR tanks had a strong influence on the tank development of all the belligerent nations. It is enough to point out that the body shape of the T-34 tank was copied practically in its entirety by the designers of the Panther tank and is reflected in the King Tiger tank and in some of the Allied tanks.

The practice of World War II showed a definite tendency towards increasing armor thickness, improving the shape of tank bodies and turrets, and the widespread adoption of steel castings in tank production.

From 1936 to 1945, the thickness of tank armor increased an average of five times, while in the same period, the maximum speed of tanks increased only 10-15 percent. Towards the end of the war, thinly armored light tanks went out of use because they did not provide sufficient protection against the mass utilization of antitank weapons (artillery, rocket-cumulative arms).

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Increasing armor thickness of tanks was achieved at the cost of complete abandonment of multiple turrets. The tanks of World War II were single turret, making it possible to reduce the total length and width of the tank body, and to increase armor thickness considerably. Thus, the British prewar Independent tank, which had five turrets and weighed approximately 40 tons, was 10 meters long, while the wartime single-turret USSR KV tank was 7 meters long. With a slight difference in weight of the two tanks, the armor of the KV was three times as thick as the armor of the Independent (75 and 25 millimeters). However, abandonment of multiple turrets brought no reduction in firepower, at least for USSR tanks. One powerful gun fully replaced two to four small-caliber guns.

In the course of the war, USSR designers further strengthened the armor protection of tanks, without increasing their size and weight, by laying out equipment and machinery efficiently. German designers could not cope with this problem, and their last tanks were approximately one-and-a-half times heavier and considerably larger than the same type USSR tank. This had its chief adverse effect on the mobility of German tanks.

Soviet designers have never lost sight of the fact that a good offense is the best defense; and while strengthening the armor of tanks, have simultaneously increased their firepower and mobility.

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